CLAIMS

1. An apparatus for a hydrocarbon reforming process, comprising:

a combustion chamber having a first end and a second end opposite the first end;

a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

at least one burner disposed in the combustion chamber, the burner adapted to combust a fuel, thereby generating a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat;

a reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner tubular portion and an outer tubular portion surrounding the inner tubular portion;

means for flowing a first mixed-feed through the first part of the reaction chamber; and

means for flowing a second mixed-feed through the annular portion of the second part of the reaction chamber counter-currently with the flow of the flue gas in the convection chamber.

2. An apparatus as in claim 1, further comprising a mixing means in the reaction chamber adapted for mixing the first mixed-feed and the second mixed-feed.

3. An apparatus as in claim 1, further comprising a means for removing a product stream from the inner tubular portion of the tube-in-tube, the product stream flowing through the inner tubular portion counter-currently with the second mixed-feed.

4. An apparatus as in claim 1, wherein the first mixed-feed flows co-currently with the flow of the flue gas in the combustion chamber.

5. An apparatus as in claim 4, further comprising at least another burner, the another burner located adjacent the second end of the combustion chamber, the another burner adapted to combust a portion of the fuel or another fuel, thereby generating a flow of another flue gas having another sensible heat, the another flue gas initially flowing in the combustion chamber counter-currently with the first mixed-feed.

6. An apparatus as in claim 4, further comprising at least another burner disposed in the combustion chamber, the another burner adapted to combust a portion of the fuel or another fuel, thereby generating a flow of another flue gas having another sensible heat, the another flue gas initially flowing in the combustion chamber in an initial direction other than co-currently or counter-currently with the first mixed-feed.

7. An apparatus as in claim 4, wherein a gas having another sensible heat is injected adjacent the second end of the combustion chamber, the gas initially flowing in the combustion chamber counter-currently with the first mixed-feed.

8. An apparatus as in claim 1, wherein the substantial portion of the first part of the reaction chamber is substantially vertical in the combustion chamber and the substantial portion of the second part of the reaction chamber is substantially vertical in the convection chamber.

9. An apparatus for a hydrocarbon reforming process, comprising:

a combustion chamber having a first end and a second end opposite the first end;

a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

at least two reaction chambers spaced apart in substantially parallel relationship, each reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner tubular portion and an outer tubular portion surrounding the inner tubular portion;

a plurality of burners disposed in the combustion chamber, each burner adapted to combust a fuel, thereby generating a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat, wherein at least one first burner is positioned between the two reaction chambers, a first reaction chamber is positioned

between the first burner and a second burner, and a second reaction chamber is positioned between the first burner and a third burner;

means for flowing a first mixed-feed through the first part of each reaction chamber co-currently with the flow of the flue gas in the combustion chamber;

means for flowing a second mixed-feed through the annular portion of the second part of each reaction chamber counter-currently with the flow of the flue gas in the convection chamber;

a mixing means in each reaction chamber adapted for mixing the first mixed-feed and the second mixed-feed; and

means for removing a product stream from the inner portion of the tube-in-tube, the product stream flowing through the inner tubular portion counter-currently with the second mixed-feed.

10. An apparatus for a hydrocarbon reforming process, comprising:

a combustion chamber having a first end and a second end opposite the first end;

a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

at least one reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner

tubular portion and an outer tubular portion surrounding the inner tubular portion;

a plurality of burners disposed in the combustion chamber, each burner adapted to combust a fuel, thereby generating a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat, wherein the reaction chamber is positioned between a first burner and a second burner;

means for flowing a first mixed-feed through the first part of the reaction chamber co-currently with the flow of the flue gas in the combustion chamber;

means for flowing a second mixed-feed through the annular portion of the second part of the reaction chamber counter-currently with the flow of the flue gas in the convection chamber;

a mixing means in the reaction chamber adapted for mixing the first mixed-feed and the second mixed-feed; and

means for removing a product stream from the inner portion of the tube-in-tube, the product stream flowing through the inner tubular portion counter-currently with the second mixed-feed.

11. A method for producing a product from a steam reforming process, comprising to the steps of:

providing a combustion chamber having a first end and a second end opposite the first end;

providing a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a

second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

providing a reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner tubular portion and an outer tubular portion surrounding the inner tubular portion;

combusting a fuel in the combustion chamber, thereby generating a combustion heat and a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat;

feeding a first mixed-feed to the first part of the reaction chamber, wherein at least a portion of the first mixed-feed absorbs at least a portion of the combustion heat; and

feeding a second mixed-feed to the annular portion of the second part of the reaction chamber, wherein the second mixed-feed flows counter-currently with the flow of the flue gas in the convection chamber, whereby at least a portion of the second mixed-feed absorbs at least a portion of the sensible heat.

12. A method as in claim 11, comprising the further step of mixing the first mixed-feed and the second mixed-feed in the reaction chamber.

13. A method as in claim 11, comprising the further step of removing a product stream from the inner tubular portion of the tube-in-tube, the product stream flowing through the inner tubular portion counter-currently with the second mixed-feed.

14. A method as in claim 11, wherein the first mixed-feed flows co-currently with the flow of the flue gas in the combustion chamber.

15. A method as in claim 14, comprising the further step of:

combusting a portion of the fuel or another fuel near the second end of the combustion chamber, thereby generating another combustion heat and a flow of another flue gas having another sensible heat, wherein the another flue gas initially flows in the combustion chamber counter-currently with the first mixed-feed.

16. A method as in claim 14, comprising the further step of:

combusting a portion of the fuel or another fuel in the combustion chamber, thereby generating another combustion heat and a flow of another flue gas having another sensible heat, wherein the another flue gas initially flows in the combustion chamber in an initial direction other than co-currently or counter-currently with the first mixed-feed.

17. A method as in claim 14, comprising the further step of:

injecting a gas having another sensible heat near the second end of the combustion chamber, the gas initially flowing in the combustion chamber counter-currently with the first mixed-feed.

18. A method as in claim 11, wherein the substantial portion of the first part of the reaction chamber is substantially vertical in the combustion chamber and the substantial portion of the second part of the reaction chamber is substantially vertical in the convection chamber.

19. A method for producing a product from a steam reforming process, comprising the steps of:

providing a combustion chamber having a first end and a second end opposite the first end;

providing a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

providing at least two reaction chambers spaced apart in substantially parallel relationship, each reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner tubular portion and an outer tubular portion surrounding the inner tubular portion;

providing a plurality of burners disposed in the combustion chamber, each burner adapted to combust a fuel, wherein at least one first burner is positioned between the two reaction chambers, a first reaction chamber is positioned between the first burner and a second burner, and a second reaction chamber is positioned between the first burner and a third burner;

combusting a fuel in the burners, thereby generating a combustion heat and a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat;

feeding a first mixed-feed to the first part of each reaction chamber, wherein the first mixed-feed flows co-currently with the flow of the flue gas in the combustion chamber, and at least a portion of the first mixed-feed absorbs at least a portion of the combustion heat;

feeding a second mixed-feed to the annular portion of the second part of each reaction chamber, wherein the second mixed-feed flows counter-currently with the flow of the flue gas in the convection chamber, whereby at least a portion of the second mixed-feed absorbs at least a portion of the sensible heat;

mixing the first mixed-feed and the second mixed-feed in each reaction chamber; and

removing a product stream from the inner portion of the tube-in-tube, wherein the product stream flows through the inner tubular portion counter-currently with the second mixed-feed.

20. A method for producing a product from a steam reforming process, comprising the steps of:

providing a combustion chamber having a first end and a second end opposite the first end;

providing a convection chamber in fluid communication with the combustion chamber, the convection chamber having a first end and a second end opposite the first end, the first end of the convection chamber being adjacent the second end of the combustion chamber;

providing at least one reaction chamber having a first part and a second part in fluid communication with the first part, a substantial portion of the first part being disposed in the combustion chamber and a substantial portion of the second part being disposed in the convection chamber, wherein the second part is a tube-in-tube having an annular portion between an inner tubular portion and an outer tubular portion surrounding the inner tubular portion;

providing a plurality of burners disposed in the combustion chamber, each burner adapted to combust a fuel, wherein the reaction chamber is positioned between a first burner and a second burner;

combusting a fuel in the burners, thereby generating a combustion heat and a flow of a flue gas from the combustion chamber to the convection chamber, the flue gas having a sensible heat;

feeding a first mixed-feed to the first part of the reaction chamber, wherein the first mixed-feed flows co-currently with the flow of the flue gas in the combustion chamber, and at least a portion of the first mixed-feed absorbs at least a portion of the combustion heat;

feeding a second mixed-feed to the annular portion of the second part of the reaction chamber, wherein the second mixed-feed flows counter-currently with the flow of the flue gas in the convection chamber, whereby at least a portion of the second mixed-feed absorbs at least a portion of the sensible heat;

mixing the first mixed-feed and the second mixed-feed in the reaction chamber; and

removing a product stream from the inner portion of the tube-in-tube, wherein the product stream flows through the inner tubular portion counter-currently with the second mixed-feed.

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